Newbury Neck Quadrangle, Maine

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GEOLOGIC HISTORY

ORIGIN OF THE STRATIFIED ROCKS

The Ellsworth Schist, which underlies most of the map area, consists of a pile of weakly metamorphosed sedimentary and igneous rocks 4 to 7 kilometers thick. The majority of the Ellsworth Schist is a metamorphic rock called schist, which gives its name to the formation. Schist originated as sediments that were eroded from nearby volcanic materials and deposited in an ocean in Cambrian time (see Geologic Time Scale below). The volcanic materials probably included lava flows and deposits of rock fragments of various sizes. Most of the schists are very thinly layered rocks and represent fine-grained sediments such as mud and silt that have since been changed by heat and pressure into schist. A few quartzite beds (**Photo 1**) were originally layers of sand. A thin conglomerate unit at the head of Morgan Bay (**Єems**) was originally a layer of pebbly gravel. These layers indicate the sediments originally accumulated in a basin near land. A part of the Ellsworth Schist that has more quartzite layers than other parts is indicated on the map by the symbol **Єem**.

Thin sheets of igneous rock are widespread in the Ellsworth Schist. Igneous rocks originate from molten rock, or magma, that cools and solidifies. Most of the igneous rocks in the Ellsworth Schist are of two types, a dark greenish gray rock called greenstone (**Photo 2**) and a white to cream-weathering rock called rhyolite (**Photo 3**). Greenstone forms from dark gray to black lava flows or volcanic ash (of basaltic composition) which has been altered through chemical reactions to produce a rock rich in the dark green mineral chlorite. Rhyolite is of a chemical composition different from greenstone, the same composition as granite. But in contrast to slowly-cooled granite, rhyolite cools rapidly from the molten state to form a uniform, hard, crystalline rock with very small mineral grains. The association of greenstone and rhyolite, together with other chemical characteristics determined by laboratory analysis, suggests the igneous rocks of the Ellsworth Schist formed in a continental rift (see Stewart, 1998). Most of these igneous rocks formed when lava erupted at the earth's surface, in some cases violently, during the time the sediment was accumulating. A few igneous sheets, however, solidified more slowly below the ground surface as indicated by their larger grain size and crosscutting relationships (**Photo 4**). The unit **Єer** at the eastern side of the map is composed largely of rhyolite produced during a larger volcanic episode. The unit **Єee** at the northeast corner of the map, though poorly exposed, appears to contain a higher proportion of greenstone than does the Ellsworth Schist elsewhere in the map area.

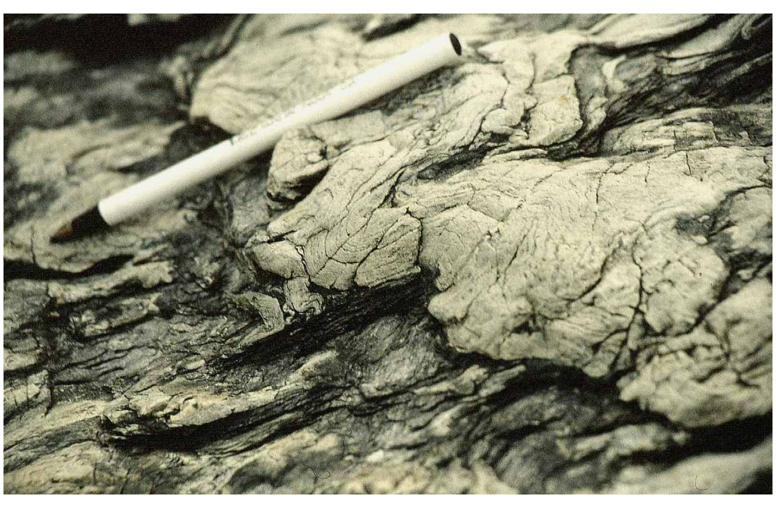

Photo 1. Thin layer of white quartzite in gray schist. Such well-defined quartzite layers are rare in most of the Ellsworth Schist. (*East shore of Newbury Neck, 4000 feet north of Curtis Cove.*)

Photo 2. Greenstone sheet four inches thick, parallel to foliation in the schist. View looking north. (*Weymouth Point, mouth of Union River.*)

Photo 3. White rhyolite. The dark fragment within the rhyolite is a fragment of a different rock type. This demonstrates that the rhyolite layer is an accumulation of rock fragments, formed by a violent volcanic eruption. (*East shore of Newbury Neck, 6000 feet north of Curtis Cove.*)

Photo 4. Angular chunk of rhyolite in greenstone. The light and dark spots in the greenstone are relatively large mineral grains that indicate this igneous sheet solidified underground. (*North end of Morgan Bay.*)

ROCK DEFORMATION AND RELATED METAMORPHISM

The Ellsworth Schist has been deformed at least three times, producing a highly contorted rock structure. In the main stage of deformation, wet sediments together with the interlayered volcanic materials were squeezed from the sides, piling up toward the northwest. Distorted thin layers show that the rocks were crumpled into folds inclined toward the northwest (**Photo 5**). Curved shapes, called shear bands, also indicate the upper part of the formation was pushed toward the northwest over the lower part (**Photo 6**). This deformation affected the entire mass of the Ellsworth Schist. The most pervasive feature of every outcrop is the main foliation, a microscopic alignment of flat mineral grains giving the rock an overall sheet-like structure. On the face of foliation surfaces, mineral grains have been stretched into lines to produce a mineral lineation. This lineation may be defined by elongate quartz grains or trails of broken minerals such as feldspar and pyrite. In most places the lineation is oriented in a northwest-southeast direction as represented by symbols on the map.

The minerals that comprise the main foliation, chlorite and white mica, are metamorphic minerals that form at elevated temperatures, typically 350 to 400 degrees Centigrade. It is due to this heat that the rocks could be deformed by folding rather than by breaking. Also during the heating, milky white quartz veins formed in the schist. These veins are scattered throughout the formation and were deformed along with the rest of the rock (**Photo 7**). The age of this deformation and metamorphism is not known very precisely; it must be younger than the Cambrian age of the Ellsworth Schist which is deformed, and older than the Devonian granite of Blue Hill which is not deformed.

The main foliation and lineation of the Ellsworth Schist were affected by a variety of later folds (**Photo 8**). Some of them appear to indicate movement towards the southeast, in a direction opposite to the earlier main stage movement toward the northwest. Late folds are particularly well-displayed at High Head in a zone of complex deformation 500 meters wide.

Following the two stages of folding, a few late brittle faults occurred in the area. The rocks at Weymouth Point are broken along steeply inclined faults approximately parallel to the length of Patten Bay (**Photo 9**). The orientation of these minor faults suggests that an old fault trace may lie beneath Patten Bay. Another piece of circumstantial evidence is the presence of metamorphic biotite (black mica) south of Patten Bay and its absence north of the bay. While this difference might be just the original metamorphic pattern, it might also be explained by a fault, as shown on the map by the truncated metamorphic isograd line. Clearly, this large fault is not proven to exist; it is inferred from the minor faults observed in outcrop. The faults may be related to an extension of the crust in a northwest-southeast direction. The age of the faults is probably younger than the Devonian granite of Blue Hill and may be Mesozoic.

Photo 5. Lower part of photo shows quartzite layers and an early foliation deformed into folds. The asymmetry of the folds indicates the top moved towards the northwest (left). Upper part of photo shows the main foliation is also inclined to the left. (*North shore of Western Bay, opposite Alley Island. View toward the northeast.*)

Photo 6. White quartz veins in schist deformed by horizontal shear bands. The sense of curvature of the quartz vein tails indicates top-to-the-northwest (left) movement. The quartz vein to the right of the penny is very tightly folded. (*West shore of Union River Bay south of Patten Bay. View toward the northeast.*)

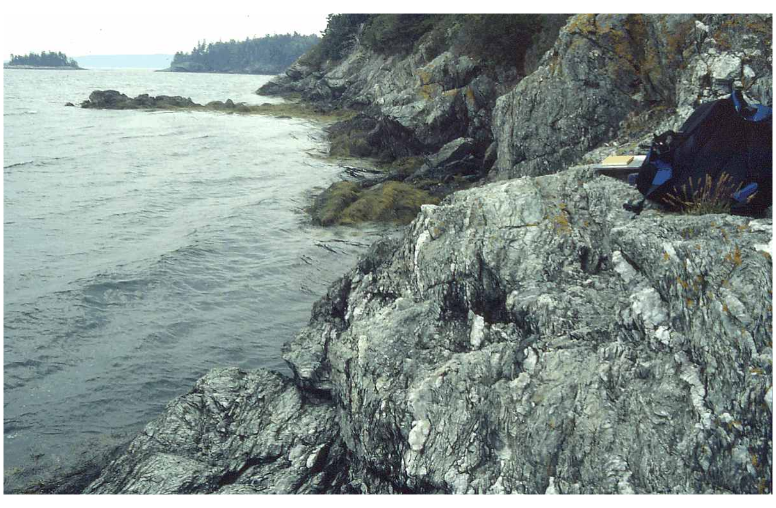

Photo 7. Typical shoreline exposure of contorted Ellsworth Schist, looking south at High Head toward Goose Rock. White quartz veins in foreground formed during metamorphism. (*South end of Newbury Neck.*)

Photo 8. Small, late folds deform layering and foliation in Ellsworth Schist. These particular ones indicate movement to the north, though most late folds are asymmetric toward the south. (*Goose Rock, south end of Newbury Neck.*)

Photo 9. Sheet of greenstone parallel to the main foliation in schist. A late, brittle fault to the right of the notebook has offset the left (southeasterly) block downward by more than a foot with respect to the equivalent rocks on the right. (*West shore of Union River, north of Weymouth Point.*)

INTRUSIVE ROCKS AND RELATED METAMORPHISM

After the folding and metamorphism of the Ellsworth Schist, melting of rocks at depth produced the Blue Hill granite (**Dge**, **Dgs**, **Dgl**) in the Devonian Period. A large mass of molten rock was intruded into the Ellsworth Schist, approximately parallel to the dominant layering. The granite is now at ground level at the west edge of the map area, and probably extends underground for some distance beneath Morgan Bay to the east. Near the top of the granite body in Webber Cove, there are impressive rocks called pegmatite that have unusually large mineral grains (**Photo 10**). These probably formed due to higher concentrations of dissolved fluids near the top of the molten rock mass as it was solidifying. Heat from the granite caused the overlying Ellsworth Schist to be heated, and new metamorphic minerals grew at the expense of chlorite and white mica. In the hottest region close to the granite, large grains of the mineral andalusite formed (**Photo 11**), and farther away from the granite small grains of biotite (black mica) grew. The presence of biotite causes the rock to be distinctly gray, in contrast with the dark greenish color of rocks outside the biotite zone which are dominated by the mineral chlorite.

Photo 10. Large mineral grains in pegmatite. White = quartz, off-white = feldspar, black = tourmaline. (*Webber Cove, west side of Morgan Bay.*)

Photo 11. Andalusite crystals in Ellsworth Schist. This mineral grew in response to heating of rocks around the Blue Hill granite. (*North end of Morgan Bay.*)

PRESENT EXPOSURE

All the metamorphic and intrusive bedrock in the map area originally formed at depth in the earth. In order for these rocks to be exposed at the surface now, a significant amount of overlying rock must have been eroded in the hundreds of millions of years since the Devonian Period. The latest increment of erosion occurred during the last Ice Age, when a continental glacier extended across Maine and ground down some of the bedrock surface. When the last glacier melted from the Maine coast, about 14,000 years ago, it deposited a layer of sediment burying most of the bedrock in the area. These sediments are described on surficial geologic maps, available from the Maine Geological Survey.